

## Embodiment #1

### Vertical channel guide

Etch Via in Silicon



FIG. 1A

Coat Sidewall with low refractive index material to provide the function of waveguide cladding layer

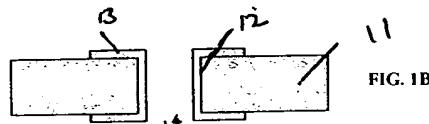


FIG. 1B

Fill the via with high refractive index material to provide the function of waveguide core layer



FIG. 1C

Maintain spot size through Si substrate using difference in index of refraction between core and clad layers

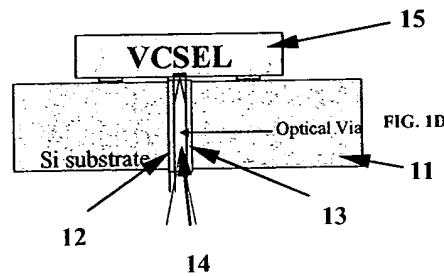


FIG. 1D

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## Embodiment #2

### Vertical channel guide thru Silicon core

Etch Vias in Silicon

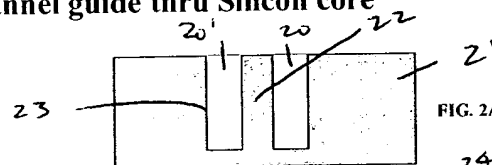


FIG. 2A

Coat Sidewall with low refractive index material to provide the function of waveguide cladding layer

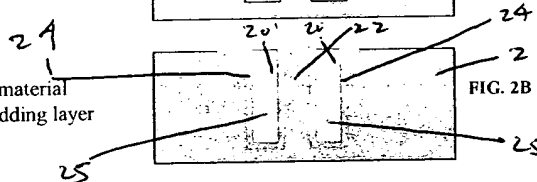


FIG. 2B

Guide the light with controlled divergence through substrate. Assumes wavelength transparent in Si Clad with polymer or nitride annular ring filled with polymer

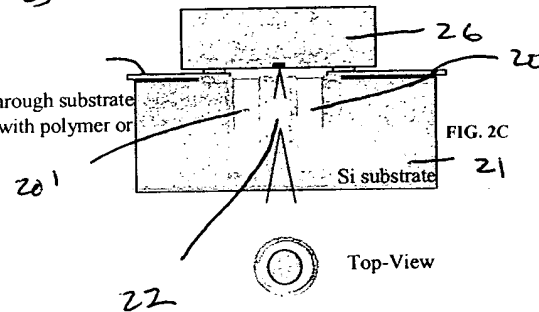


FIG. 2C

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### Embodiment #3

### Electro-optical Via

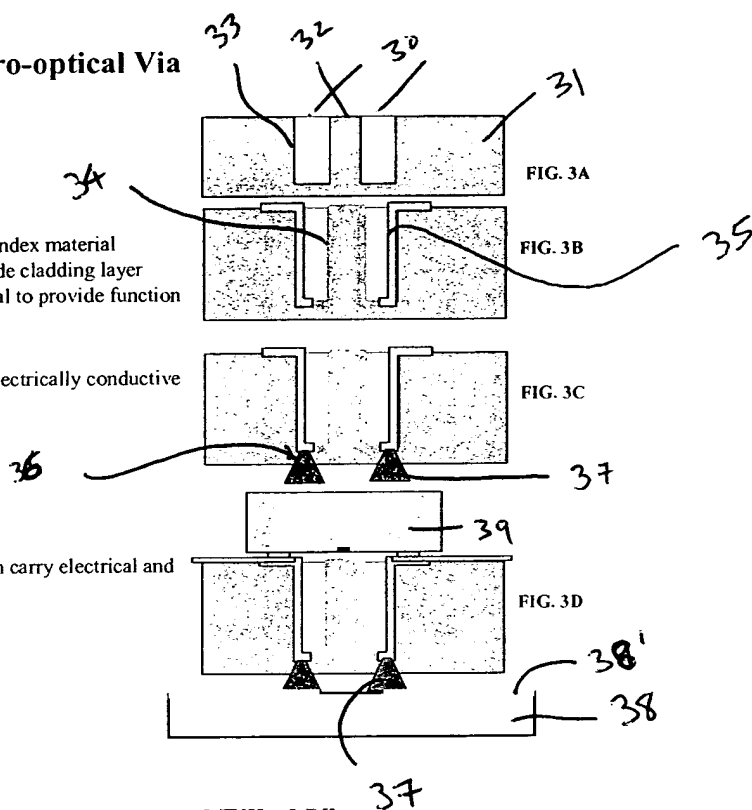
Etch Vias in Silicon

Coat Sidewall with low refractive index material to provide the function of waveguide cladding layer  
And electrically conductive material to provide function Of electrical conduction

Form electrical connection to the electrically conductive material

Attach device; Formed structure can carry electrical and Optical signals.

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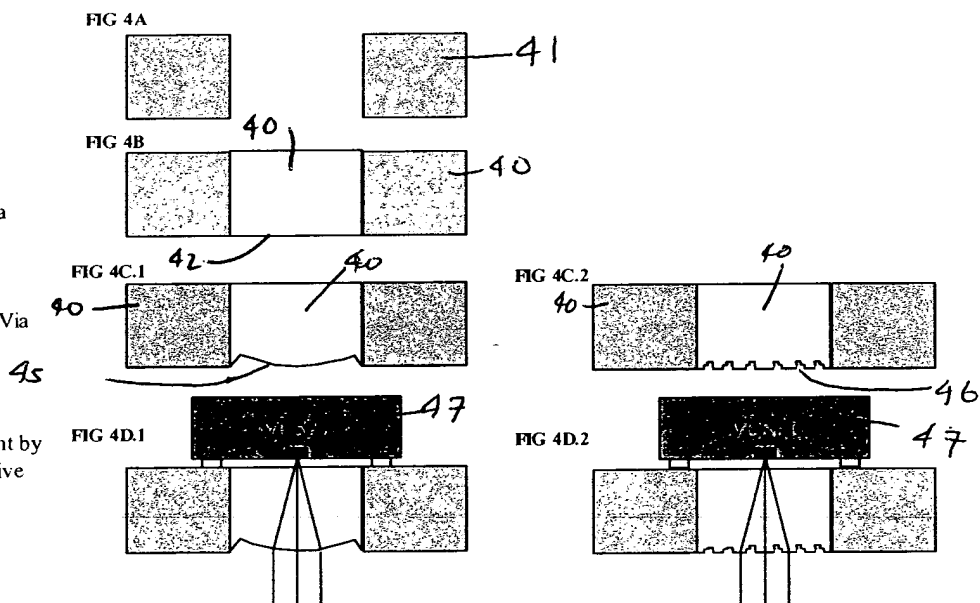
### Embodiment #4: Backside Patterned Filled Vias

Etch Vias in Silicon

Fill Vias with transparent media

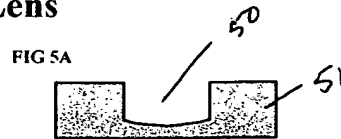
Etch the backside of the Filled Via

Etched Patterns redirect the light by refractive (e.g. lens) or diffractive (e.g. grating) optics

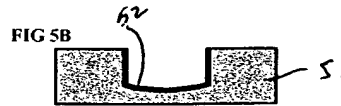


## Embodiment 5: Via with Lens

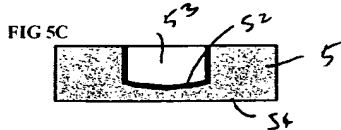
Etch Vias in Silicon



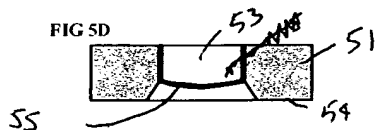
Deposit Etch Stop Layer  
(e.g. Nitride Layer)



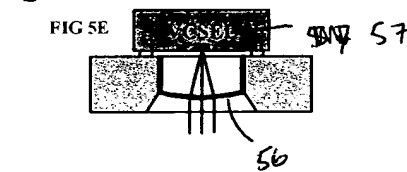
Fill with Transparent Media



Open Via by Backside Etch

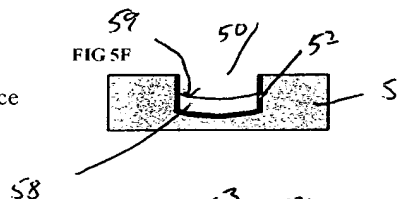


The via etch produces a  
curved surface at the bottom  
of the via that acts as a lens

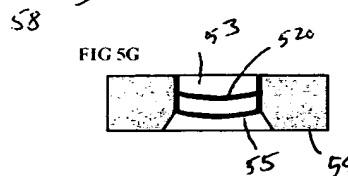


## Embodiment 5: Via with Lens, alternate

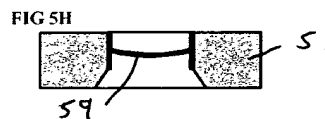
Fill With Sacrificial Material With  
Appropriate Surface Tension to Produce  
Lensing Miniscus (e.g. organic)



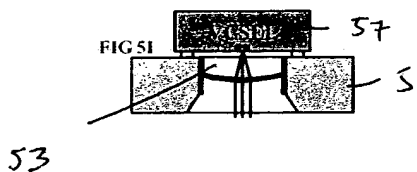
Deposit Etch Stop (e.g. Nitride),  
Fill with Transparent Media,  
Open Via with Backside Etch



Remove Etch Stop Layer,  
Remove Sacrificial Material

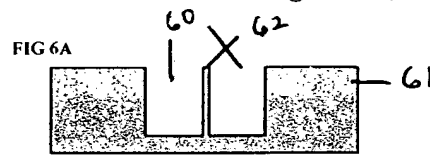


The curved surface formed by the  
miniscus acts as a lens

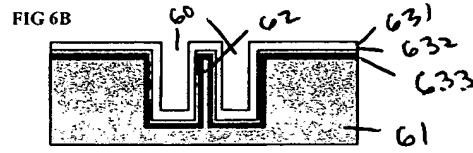


## Embodiment #6: Discrete Index Gradient Guiding Pillar, for wavelength $>1\ \mu\text{m}$

Etch Annular Ring in Silicon, small diameter center post (e.g.  $5\ \mu\text{m}$ )



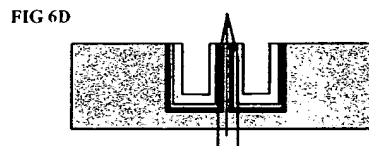
Sequentially deposit layers with decreasing index with until diameter is larger enough to capture all of the light



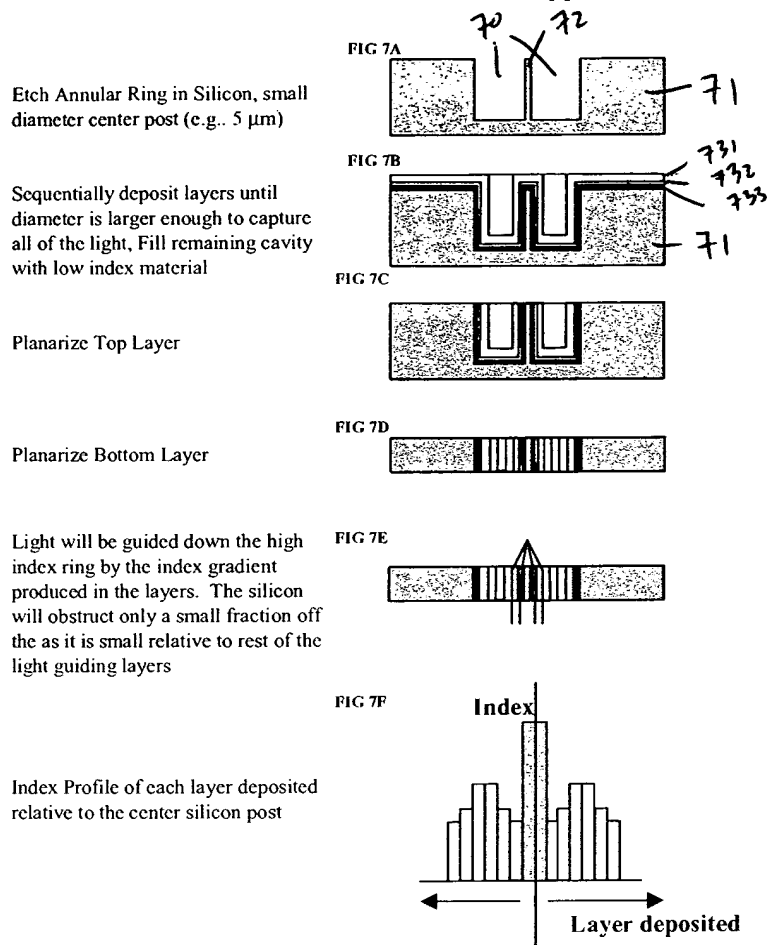
Planarize Top Layer



Light will be guided down the small diameter silicon core by the index gradient produced in the layers

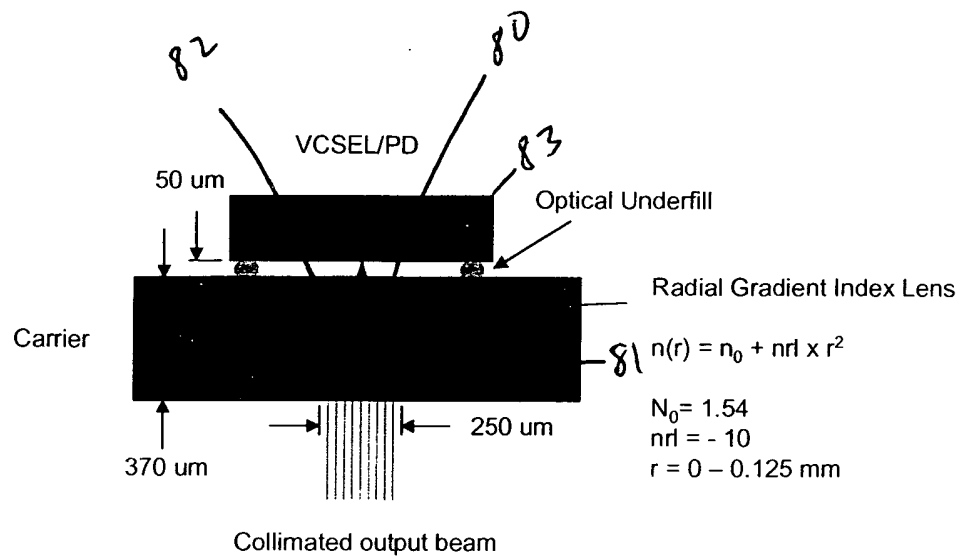


### Embodiment #7: Discrete Index Gradient Support Pillar, intended for wavelength $< 1 \mu\text{m}$

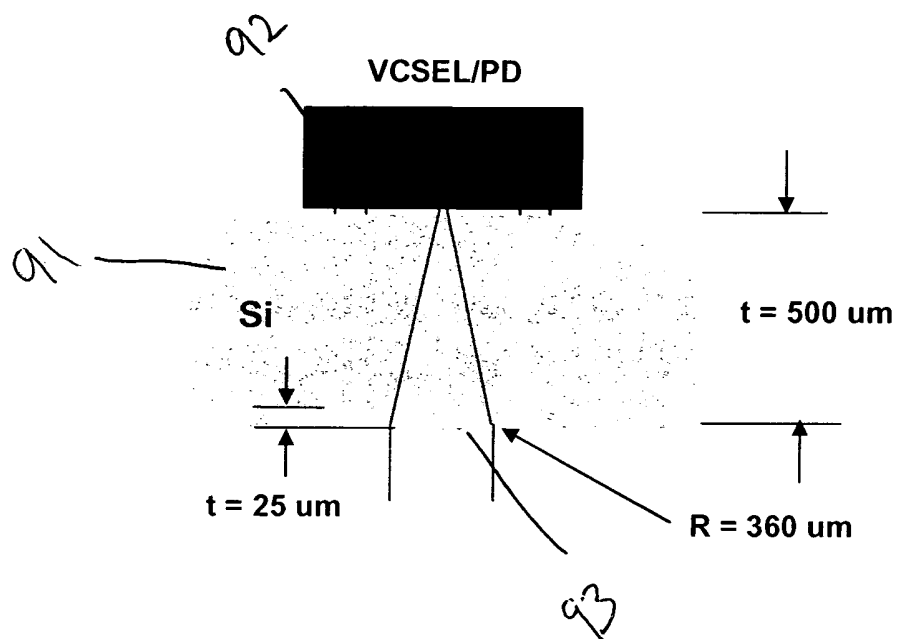


**FIG. 8 Carrier with Integrated Gradient Index Microlenses**

**FIG. 8 Carrier with Integrated Gradient Index Microlenses**



**FIG. 9 Lens Etched into Backside of Si Carrier**



**Embodiment #10    Carriers with Attached Microlens Arrays**

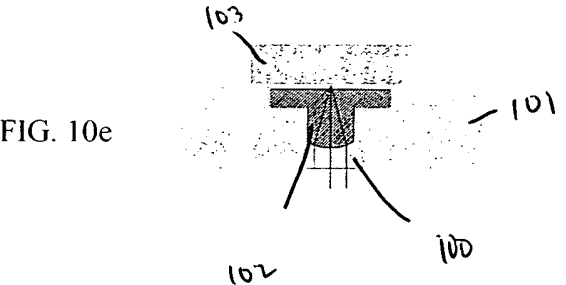
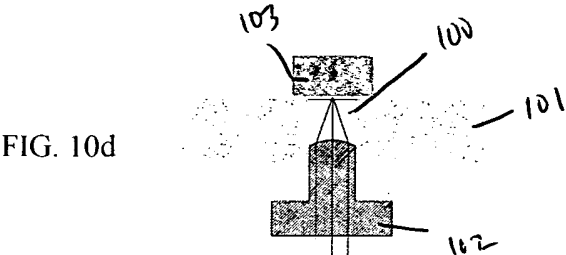
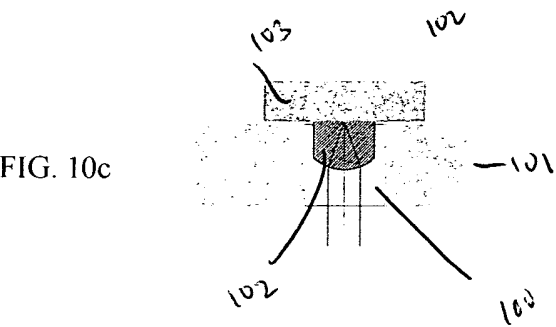
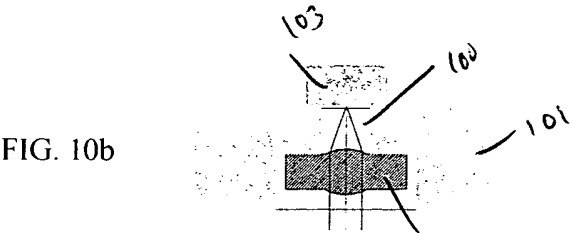
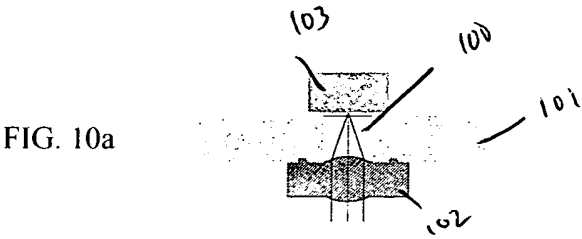




FIG. 11 Typical Use

